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SOLAR/2068-79/05

Monthly Performance Report

COLUMBIA GAS SYSTEM

MAY 1979



U.S. Department of Energy

National Solar Heating and
Cooling Demonstration Program

National Solar Data Program

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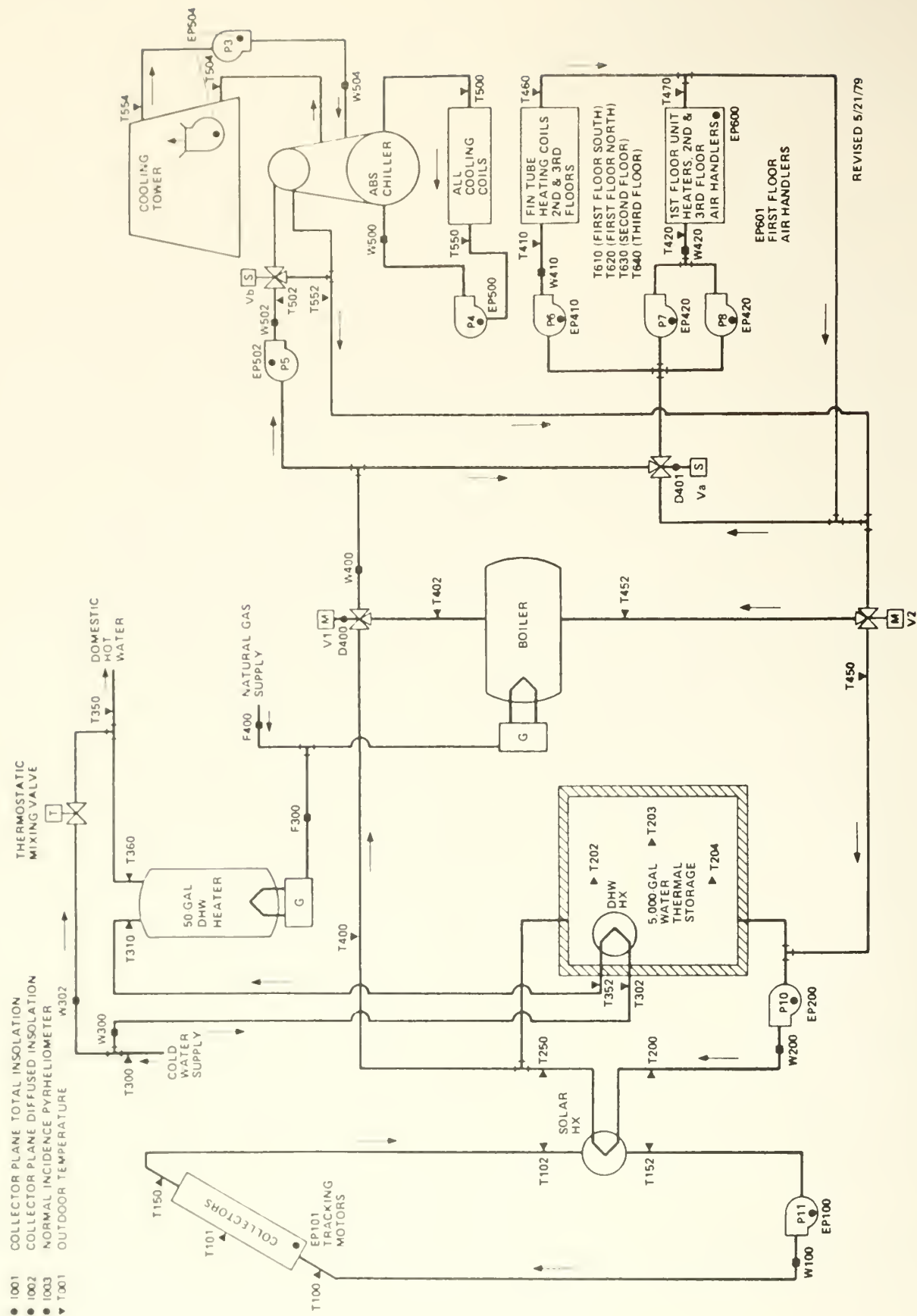
MONTHLY PERFORMANCE REPORT
COLUMBIA GAS SYSTEM
MAY 1979

I. SYSTEM DESCRIPTION

The Columbia Gas System site is a three-story, 25,000 square foot office building in Columbus, Ohio. The solar energy system, which was added to the existing building, is designed to provide 30 percent of the building's total annual thermal energy requirements. The expected annual solar contributions for the three subsystems are 32 percent for space heating, 23 percent for space cooling, and 70 percent for hot water. The collector subsystem is comprised of 44 Honeywell, Inc. north/south tracking, concentrating collectors, facing five degrees east of south. The collectors rotate about an approximate east/west axis to track the daily variation in the sun's elevation angle, and direct the solar radiation toward the absorber tube mounted above the reflectors. The collector array is arranged in 11 rows with a total gross area of 2,978 square feet.

The collector loop heat transfer fluid is a 47 percent solution of Dowtherm SR1. Collected solar energy is transferred to the loads, or to a 5,000-gallon water thermal storage tank via a liquid-to-liquid heat exchanger. Incoming city water is heated for use as domestic hot water on demand, by passing it through another heat exchanger, or preheat coil, located within the water thermal storage tank. A conventional 50-gallon gas-fired hot water heater augments this solar hot water energy from the tank heat exchanger. Solar heated water is also used for space heating and cooling. This thermal energy is supplied either to fin tube heating coils for space heating, or to an absorption chiller for space cooling. When solar energy is insufficient to satisfy heating or cooling demands, thermal energy is provided by an auxiliary gas-fired boiler.

The solar energy system, shown schematically in Figure 1, has six modes of operation which are defined as follows:



Mode 1 - Collectors Tracking: In this mode, the collectors track the sun to collect solar energy. This mode is entered by a four-step process:

- 1) If measured insolation in the principal plane of the collector is greater than approximately $175 \text{ Btu/ft}^2\text{-hr}$, storage tank temperature is less than 210°F , wind speed is less than 20 mph, and collector array outlet temperature is less than 240°F , then collector loop pump P11 is turned on. At this time a closed valve (not shown in Figure 1) allows collector loop flow to bypass the primary side of the collector loop heat exchanger.
- 2) If flow is detected in the collector loop by a differential pressure switch, the collectors are rotated to the correct tracking position.
- 3) When the collectors have reached the tracking position, a differential temperature controller checks the collector outlet temperature to determine if it is at least 20°F greater than the storage temperature.
- 4) If this temperature differential is detected, storage loop pump P10 is turned on to allow flow through the secondary side of the heat exchanger, and the collector loop heat exchanger bypass valve is opened to allow flow through the primary side of that heat exchanger.

The collectors remain in Mode 1 until conditions are met for returning the system to Mode 2 or Mode 3. While in Mode 1, if the collector outlet temperature drops to less than 5°F above the storage tank temperature, then storage loop pump P10 is turned off and the collector loop bypass valve is closed to bypass the primary side of the heat exchanger. The collectors continue to track the sun and collector loop circulation is maintained until the 20°F temperature differential is again met, or until conditions for return to Mode 2 or Mode 3 are met.

Mode 2 - Collectors Stowed: While in Mode 2, the collector reflectors are turned downward toward the roof, or stowed, to prevent collector damage from excessive heat or the elements. This mode is entered from Mode 1 by a two-step process:

- 1) While in Mode 1, if one or more of five conditions is met, the collectors are placed in the stowed position. These five conditions are: a. wind speed greater than 30 mph for approximately 10 seconds; b. measured insolation in the principal plane of the collector less than approximately 150 Btu/ft²-hr; c. differential pressure switch senses no flow in the collector loop; d. collector array outlet temperature greater than 252°F; and e. storage tank temperature greater than 220°F.
- 2) When the collectors have returned to the stowed position, storage loop pump P10 is turned off, the primary side of the collector loop heat exchanger is bypassed, and collector loop pump P11 is turned off.

If the collectors were stowed due to an absence of collector loop flow, manual reset is required before Mode 1 can be reentered. However, if the collectors were stowed for any of the other four conditions, Mode 1 will be reentered automatically whenever its entry conditions are met.

Mode 3 - Collector Emergency Stow: This mode is used to stow the collectors in the event of a power failure. This mode is entered from Mode 1 by a four-step process:

- 1) If voltage-sensitive relays in all tracking motor phases detect that any phase has dropped below 70 percent rated voltage, an emergency generator is activated.
- 2) When the generator has reached operating voltage, transfer switches automatically transfer the control system and collector loop pump P11 from the normal building power to the emergency generator.

- 3) The collector controls cause the collectors to move from the tracking position to the stowed position in four stages (or steps) using power from the emergency generator. During each of the four stages, approximately one-fourth of the total collector array will be stowed.
- 4) When all collectors have been stowed, the collector loop pump is turned off. The controls are then reset for return to Mode 1 operation when building power is restored.

When building power has been restored, power transfer switches automatically return to building power. After a 10-minute delay, the emergency generator is turned off, and Mode 1 is reentered if its entry conditions are met.

Mode 4 - Solar Energy-to-Space Heating/Cooling: This mode occurs when there is a demand for space heating or cooling and the storage tank temperature exceeds the minimum value suitable for the loads. If summer operation has been manually selected by a master controller, this value is 190°F. If winter operation has been selected, solar energy flow begins at 150°F. These temperature settings are nominal values and can be adjusted by site personnel if desired. When this control temperature setting has been exceeded, the boiler gas supply is immediately shut off and flow continues through the boiler for two minutes to deplete some of the residual energy. The load supply lines are then switched from auxiliary to solar energy. When the storage temperature has dropped by 2°F, Mode 4 is terminated. If storage loop pump P10 is operating while Mode 4 is active, part of the energy supplied to the loads will come directly from the heat exchanger and the balance will come from storage. If this pump is not operating, all the solar energy supplied to the loads originates from storage.

Mode 5 - Collector-to-Storage: This mode occurs while the collectors are operating in Mode 1, but the conditions for Mode 4 entry are not met.

While in this mode, solar energy is routed directly from the collectors to storage via the collector loop heat exchanger. Mode 5 is terminated upon entry to Mode 2, 3 or 4.

Mode 6 - Storage-to-Domestic Hot Water: This mode occurs while a domestic hot water demand is present. When hot water is being used, makeup cold water flows by supply pressure through the hot water preheat coil in the storage tank. This makeup water absorbs stored solar energy as it passes enroute to the conventional hot water heater.

In addition to these six modes, individual collector rows can be stowed if they overheat. Each of the 11 individual collector rows has a separate control system sensor indicating absorber tube temperature. If the temperature of an individual collector row absorber tube exceeds 260°F, that collector row is stowed. When the temperature then drops below 220°F, that collector row resumes tracking. If the collector row overheats a second time, a manual reset is required to restart the individual collector row.

II. PERFORMANCE EVALUATION

The system performance evaluations discussed in this section are based primarily on the analysis of the data presented in the attached computer-generated monthly report. This attached report consists of daily site thermal and energy values for each subsystem, plus environmental data. The performance factors discussed in this report are based upon the definitions contained in NBSIR 76-1137, Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program.

A. Introduction

The solar energy system at the Columbia Gas site collected energy on 24 days during May and supplied 5.0 percent of the total system thermal energy load. Space heating, space cooling, and domestic hot water heating received 15.5 million Btu of solar energy during the month. Although average storage temperatures exceeded the 150°F control set point for

heating on 26 days during the month, little solar energy was used for space heating due to the master controller being set for summer operation, which has a 190°F set point. Space heating was required on 29 days. Space cooling was required on 30 days.

B. Weather

May is typically a transitional month in Columbus, with a long-term average outside ambient temperature of 61°F, 176 heating degree-days, and 55 cooling degree-days. This month the actual outside ambient temperature average was 63°F, 137 heating degree-days and 74 cooling degree-days were experienced. The measured insolation in the plane of the pyranometers (five degrees east of south, with a tilt of 40 degrees from the horizontal) averaged 1,512 Btu/ft²-day, which is slightly less than the expected long-term average of 1,648 Btu/ft²-day. This reduction in available solar energy was responsible for a slight decrease in solar energy system performance.

C. System Thermal Performance

Collector - Of the 139.6 million Btu of incident solar energy on the collector array during May, 82.0 million Btu were incident on the array while collection and storage pumps P11 and P10 were operating. The system collected 28.0 million Btu, or 20.0 percent of the total insolation incident on the collector array. This was 34.0 percent of the insolation incident while the pumps were operating. Since these collectors are tracking concentrators, they use only the direct or beam component of solar energy. While pumps P10 and P11 were operating and the collectors were tracking the sun during May, a total of 75.4 million Btu of direct solar energy was incident on the collector array. Of this incident direct solar energy, 37.0 percent was collected by the array, which agrees closely with the 37.9 percent collected in April. During May, pumps P10 and P11 and the collector tracking motors used a combined total of 1.70 million Btu of electrical energy.

Storage - Of the 27.97 million Btu of solar energy collected, 21.49 million Btu were delivered to the storage tank. A total of 8.00 million Btu of solar energy was extracted from the storage tank. A total of 4.07 million Btu of solar energy was extracted from the storage tank to preheat domestic hot water. The net energy in storage increased by 0.61 million Btu during the month. A summary of energy in and out of storage is shown below. The net thermal loss from storage was 12.88 million Btu.

21.49	million Btu	-	energy to storage tank
<u>8.00</u>	million Btu	-	energy extracted from storage tank
13.49	million Btu		
<u>- 0.61</u>	million Btu	-	energy increase in storage tank
12.88	million Btu	-	thermal loss from storage tank

Domestic Hot Water Load - The domestic hot water subsystem operated continuously during May. The daily average hot water consumption was 186 gallons for the month. The 5.16 million Btu of energy added to the subsystem were comprised of 4.07 million Btu of solar energy and 1.10 million Btu of auxiliary thermal energy, giving a hot water solar fraction of 79 percent. Hot water was supplied at an average temperature of 119°F and was replaced with cold water at an average temperature of 64°F.

Space Heating Load - Space heating was required on 29 days during May. The space heating load of 82.5 million Btu was supplied by 81.5 million Btu of auxiliary thermal energy and 1.04 million Btu of solar energy. In order to provide this auxiliary thermal energy, 164.6 million Btu of natural gas were required. The ratio of auxiliary thermal energy used to natural gas supplied showed a boiler conversion efficiency of 49.5 percent. As previously mentioned, storage temperatures must exceed 150°F before solar energy can be used for space heating. Although average storage temperatures exceeded 150°F on 26 days during May, the space heating requirements were largely provided from the boiler due to a 190°F requirement for water temperature for the absorption chiller.

Space Cooling Load - The absorption chiller required 221.1 million Btu to provide 96.6 million Btu of chilled water. Solar energy supplied 10.4 million Btu and the auxiliary boiler supplied 210.7 million Btu to the absorption chiller. In order for solar energy to be used for space cooling, the temperature in the top of the storage tank must be greater than or equal to 190°F to run the absorption chiller. If this temperature is reached, solar energy for space cooling can be supplied directly from the collector array via the heat exchanger, from storage, or from a combination of both. During this month, the top storage temperature exceeded 190°F on six days. Total elapsed time for the six days was approximately 13 hours. Calculations indicated 305.8 million Btu of natural gas were required to provide auxiliary thermal energy. The coefficient of performance of the absorption chiller was 0.44. The total space cooling load in May was 96.6 million Btu.

D. Observations

The solar energy system showed a noticeable improvement in performance in May, by supplying five percent of the system thermal energy requirement. This is attributed to a more accurate flow totalizer recently installed in the domestic hot water subsystem. For the previous six months of system operation, the net measure solar contribution was between 0.66 and 3.0 percent, which contrasts to an expected solar contribution of 30 percent. Additional activity is in progress at the site to decrease thermal losses from storage and reduce collector array tracking limitations. As this effort continues, a gradual increase in system performance is anticipated.

A problem due to inadvertent flow of hot water through heating coils at the wrong time is adding to the cooling load. For example, when the absorption chiller was operating on May 9 as much as 70°F temperature drop across the T470 and T420 sensors was observed from 0620 to 2400 hours with no flow indication on flowmeter W420. This is due to a backflow forced through pumps P6, P7 and P8 and adds appreciably to the total building cooling load. The actual added load is unknown. During the transitional

season this problem will not be easily solved. When cooling only is required, the heating coils can be isolated with manual valves and the problem will be eliminated.

A system problem exists which interferes with utilization of stored solar energy. For example, the space heating subsystem report shows that 81.5 million Btu of auxiliary thermal energy was used for space heating and 1.0 million Btu of solar energy was used for space heating; yet, the average temperature of stored water exceeded 150°F on 26 days.

The stored solar energy was available for space heating but not used. This appears to be due to "summer operation" which is manually selected by a master controller (see Section I, Mode 4). The summer operation selection causes solar energy flow from the storage tank to begin when the temperature is greater than 190°F. The heating system could efficiently use water with a temperature less than 190°F. Re-examination of the automatic control system is suggested with a goal of increasing the percent of solar energy utilized from the storage tank for space heating.

E. Energy Savings

The Columbia Gas solar energy system resulted in a savings of 25.83 million Btu of natural gas during the month. In order to operate the solar energy system, 1.70 million Btu of electrical energy were used to operate the collector tracking motors and pumps. To allow a direct comparison of natural gas savings with electrical expense, an efficiency of 30 percent was assumed for converting natural gas to electricity and transmitting that energy to the user. This shows that the 1.70 million Btu of electrical energy were equivalent to 5.66 million Btu of natural gas. Subtracting this from the solar energy fossil fuel savings of 25.83 million Btu gave a net energy savings of 20.17 million Btu of natural gas when compared to a conventional system. Computed cumulative energy savings for October through May were 27.71 million Btu of equivalent fossil energy.

III. ACTION STATUS

The solar energy system collected energy on 24 days during May and is still being refined by site personnel. As this activity continues, the solar energy system will become fully operational and carry a larger portion of the system load. Collector array modifications are in progress to improve tracking accuracy, which will increase the solar energy contribution. Site personnel are also checking the storage tank to determine the source of the high thermal losses. A maintenance visit was made on May 1 to make adjustments to the hot water instrumentation.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979

SOLAR/9959-75/05

SITE/SYSTEM DESCRIPTION:

THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS RIGLER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING CONCENTRATORS WITH A TOTAL EFFECTIVE AREA OF 2978 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOWTHERM SP1. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY

139.603 MILLION BTU
46878 BTU/SQ.FT.
27.966 MILLION BTU
9390 BTU/SQ.FT.
63 DEGPEES F
74 DEGPEES F

COLLECTED SOLAR ENERGY

AVERAGE AMBIENT TEMPERATURE
AVERAGE BUILDING TEMPERATURE
ECSS SOLAR CONVERSION EFFICIENCY
ECSS OPERATING ENERGY
TOTAL SYSTEM OPERATING ENERGY
TOTAL ENERGY CONSUMED

0.11 MILLION BTU
1.700 MILLION BTU
84.731 MILLION BTU
585.030 MILLION BTU

SUBSYSTEM SUMMARY:

LOAD
SOLAR FRACTION
SOLAR ENERGY USED
OPERATING ENERGY
AUX. THERMAL ENERGY
AUX. ELECTRIC FUEL
AUX. FOSSIL FUEL
ELECTRICAL SAVINGS
FOSSIL SAVINGS

HOT WATER
82.544
1
1.042
15.908
81.502
N.A.
164.608
N.A.
1.737
0.244

HEATING
96.562
5
10.358
67.123
210.710
N.A.
305.810
N.A.
17.264

COOLING
184.294 MILLION BTU
5 PERCENT
15.498 MILLION BTU
84.731 MILLION BTU
293.553 MILLION BTU
N.A. MILLION BTU
472.235 MILLION BTU
-1.700 MILLION BTU
25.630 MILLION BTU

SYSTEM PERFORMANCE FACTOR:

* DENOTES UNAVAILABLE DATA
N DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978.
SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979

SOLAR/9999-79/05

SITE/SYSTEM DESCRIPTION:

THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS BOILER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING CONCENTRATORS WITH A TOTAL EFFECTIVE AREA OF 2978 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOWTHERM SR1. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY

COLLECTED SOLAR ENERGY

AVERAGE AMBIENT TEMPERATURE
AVERAGE BUILDING TEMPERATURE
ECSS SOLAR CONVERSION EFFICIENCY
ECSS OPERATING ENERGY
TOTAL SYSTEM OPERATING ENERGY
TOTAL ENERGY CONSUMED

147.281 GIGA JOULES
532347 KJ/SQ.M.
29.503 GIGA JOULES
106638 KJ/SQ.M.
17 DEGREES C
24 DEGREES C
0.11
1.793 GIGA JOULES
89.391 GIGA JOULES
617.206 GIGA JOULES

SUPPLY SYSTEM SUMMARY:

LOAD
SOLAR FRACTION
SOLAR ENERGY USED
OPERATING ENERGY
AUX. THERMAL ENG
AUX. ELECTRIC FUEL
AUX. FOSSIL FUEL
ELECTRICAL SAVINGS
FOSSIL SAVINGS

HOT WATER
5.440
79
4.289
N.A.
1.167
N.A.
1.926
N.A.
7.149

HEATING
87.084
1
1.099
16.783
85.985
N.A.
173.661
N.A.
1.832
0.244

COOLING
101.873
5
10.928
70.815
222.299
N.A.
322.629
N.A.
18.214

SYSTEM TOTAL
194.430 GIGA JOULES
PERCENT
16.351 GIGA JOULES
89.391 GIGA JOULES
309.698 GIGA JOULES
N.A. GIGA JOULES
498.207 GIGA JOULES
-1.793 GIGA JOULES
27.251 GIGA JOULES

SYSTEM PERFORMANCE FACTOR:

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978,
SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT

ENERGY COLLECTION AND STORAGE SUBSYSTEM (FCSS)

SITE: COLUMBIA GAS, COLUMBUS, OHIO

SOLAR/9959-79/05

REPORT PERIOD: MAY, 1978

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO FCSS MILLION BTU	FCSS OPERATING ENERGY MILLION BTU	FCSS ENERGY REJECTED MILLION BTU	FCSS SOLAR CONVERSION EFFICIENCY
1	*	*	*	NOT	*	NOT	*
2	*	*	*	NOT	*	NOT	*
3	7.393	60	1.340	NOT	0.075	NOT	0.168
4	0.598	47	0.213	NOT	0.000	NOT	0.356
5	6.628	50	1.291	NOT	0.075	NOT	0.169
6	5.144	60	0.100	NOT	0.076	NOT	0.121
7	6.173	70	0.261	NOT	0.080	NOT	0.082
8	5.925	76	0.205	NOT	0.077	NOT	0.152
9	5.584	77	0.215	NOT	0.072	NOT	0.114
10	4.769	78	0.260	NOT	0.050	NOT	0.055
11	4.101	78	0.100	NOT	0.046	NOT	0.024
12	3.328	63	0.000	NOT	0.038	NOT	0.000
13	2.998	56	0.000	NOT	0.024	NOT	0.000
14	5.307	64	0.156	NOT	0.074	NOT	0.029
15	5.060	62	0.186	NOT	0.076	NOT	0.037
16	6.595	58	1.040	NOT	0.089	NOT	0.150
17	6.567	59	2.138	NOT	0.089	NOT	0.317
18	7.518	69	0.121	NOT	0.105	NOT	0.242
19	6.026	69	0.000	NOT	0.086	NOT	0.105
20	4.185	74	0.000	NOT	0.039	NOT	0.000
21	5.864	67	1.277	NOT	0.079	NOT	0.218
22	4.897	62	0.177	NOT	0.063	NOT	0.036
23	0.981	61	0.167	NOT	0.006	NOT	0.171
24	0.425	53	0.148	NOT	0.004	NOT	0.347
25	0.628	45	0.132	NOT	0.002	NOT	0.210
26	3.311	53	0.009	NOT	0.020	NOT	0.003
27	3.230	57	0.003	NOT	0.039	NOT	0.001
28	4.752	59	0.005	NOT	0.058	NOT	0.001
29	6.109	64	0.280	NOT	0.089	NOT	0.047
30	*	*	*	NOT	*	NOT	*
31	0.912	66	0.138	NOT	0.003	NOT	0.152
SUM	139.607	-	11.031	N.A.	1.700	N.A.	-
AVG	4.503	63	0.356	N.A.	0.055	N.A.	0.111
NPS ID	0001	N113			Q102		N111

* DENOTES UNAVAILABLE DATA.

0 DENOTES NULL DATA.

N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SOLAR/9999-79/09

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	*	*	*	*	*
2	*	*	*	*	*
3	7.383	5.147	2.064	63	0.280
4	0.599	0.000	0.000	46	0.000
5	6.628	4.553	1.812	58	0.272
6	6.144	4.174	1.444	70	0.235
7	6.173	4.413	1.340	79	0.217
8	5.025	3.815	1.354	84	0.229
9	5.584	3.405	0.964	86	0.173
10	4.769	1.743	0.528	85	0.111
11	4.101	1.375	0.707	87	0.075
12	3.328	1.289	0.147	72	0.044
13	2.998	0.473	0.101	59	0.034
14	5.303	2.206	1.016	73	0.152
15	5.060	2.488	0.838	69	0.166
16	6.595	5.341	2.034	68	0.308
17	6.567	5.321	2.155	69	0.328
18	7.518	5.981	2.387	78	0.317
19	6.026	4.879	1.524	80	0.253
20	4.185	0.000	0.000	82	0.000
21	5.964	4.019	1.276	74	0.218
22	4.897	2.744	0.620	69	0.127
23	0.981	0.000	0.000	62	0.000
24	0.425	0.000	0.000	54	0.000
25	0.628	0.000	0.000	47	0.000
26	3.311	0.000	0.000	57	0.000
27	3.230	1.583	0.433	59	0.124
28	4.762	3.048	0.997	67	0.209
29	6.199	5.054	1.918	72	0.309
30	*	*	*	*	*
31	0.912	0.000	0.000	66	0.000
SUM	139.603	81.984	27.965	-	-
AVG	4.503	2.645	0.902	68	0.200
NRSTD	0.001		0.100		0.100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT STORAGE PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979 SOLAR/9009-79/09

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORAGE ENERGY MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	*	*	*	*	*
2	*	*	*	*	*
3	1.489	0.914	1.481	175	1.609
4	0.000	0.213	-0.121	183	1.000
5	1.327	1.030	0.150	188	0.895
6	1.251	0.100	-0.1045	187	0.044
7	1.100	0.261	0.113	185	0.340
8	1.127	0.205	-0.060	186	0.128
9	0.907	0.215	-0.113	184	0.113
10	0.460	0.260	-0.121	180	0.303
11	0.235	0.100	-0.114	178	0.058
12	0.101	0.000	-0.330	173	-3.257
13	0.077	0.000	-0.320	163	-4.153
14	0.836	0.156	0.430	166	0.701
15	0.646	0.186	0.125	172	0.481
16	1.458	0.704	0.431	179	0.778
17	0.906	1.049	-0.473	180	0.636
18	2.179	0.121	0.495	175	0.094
19	1.349	0.000	-0.472	182	0.367
20	0.000	0.000	-0.448	171	1.000
21	0.580	0.749	-0.107	166	0.518
22	0.482	0.177	-0.653	158	0.588
23	0.000	0.167	-0.509	145	1.000
24	0.000	0.132	-0.446	133	1.000
25	0.000	0.009	-0.231	125	1.000
26	0.000	0.003	0.550	128	1.230
27	0.416	0.005	0.751	144	0.506
28	0.834	0.185	1.090	168	0.774
29	1.647	*	*	*	*
30	*	*	*	*	*
31	0.000	0.138	-0.804	163	1.000
SUM	21.486	8.001	0.613	-	-
AVG	0.693	0.258	0.020	168	0.401
NPS ID	0200	0201	0202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
HOT WATER SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SOLAR/9999-79/05

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FUEL LOAD PER CENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	SUP. WAT. TEMP DEG F	HOT WAT. TEMP DEG F	HOT WATER USED GAL
1	*	*	*	NOT	*	NOT	*	NOT	*	*	*	*
2	0.549	45	0.293		0.356		0.593		0.489	60	91	616
3	0.324	56	0.213		0.111		0.185		0.355	60	84	477
4	0.123	91	0.117		0.011		0.018		0.188	62	93	162
5	0.111	90	0.100		0.011		0.019		0.167	61	119	112
6	0.272	96	0.261		0.012		0.020		0.435	60	140	277
7	0.217	95	0.205		0.011		0.019		0.342	61	135	215
8	0.227	95	0.215		0.011		0.019		0.359	61	136	234
9	0.271	96	0.260		0.011		0.019		0.423	62	137	234
10	0.116	86	0.100		0.016		0.026		0.166	64	130	306
11	0.010	1	0.000		0.010		0.017		0.000	63	138	117
12	0.012	1	0.000		0.012		0.020		0.000	63	138	0
13	0.177	88	0.156		0.021		0.035		0.260	64	133	206
14	0.199	94	0.196		0.013		0.021		0.337	64	129	230
15	0.215	94	0.202		0.013		0.021		0.337	64	136	237
16	0.179	90	0.161		0.018		0.030		0.268	66	133	188
17	0.133	91	0.121		0.012		0.020		0.202	65	128	149
18	0.011	4	0.000		0.011		0.018		0.001	70	109	1
19	0.011	0	0.000		0.011		0.018		0.000	70	101	0
20	0.194	99	0.177		0.022		0.036		0.286	66	127	221
21	0.192	92	0.177		0.015		0.025		0.295	66	127	240
22	0.180	93	0.167		0.017		0.029		0.279	66	127	246
23	0.163	91	0.148		0.015		0.025		0.246	66	119	261
24	0.145	91	0.132		0.013		0.021		0.219	66	109	289
25	0.019	48	0.009		0.010		0.017		0.015	69	95	29
26	0.014	21	0.007		0.011		0.019		0.005	68	92	9
27	0.016	29	0.005		0.011		0.019		0.008	67	94	10
28	0.153	88	0.134		0.018		0.031		0.224	65	119	175
29	*	*	*		*		*		*	*	*	*
30	0.325	45	0.138		0.196		0.311		0.231	65	118	207
31												
SUM	5.156	-	4.065	N.A.	1.106	N.A.	1.826	N.A.	6.776	-	-	5772
AVG	0.166	79	0.131	N.A.	0.036	N.A.	0.059	N.A.	0.219	64	119	186
NPS	0.302	N300	0.300	0.303	0.301	0.305	0.306	0.311	0.313	N305	N307	N308

* DENOTES UNAVAILABLE DATA.
? DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
SPACE HEATING SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SCLAP/9999-79/05

DAY OF MON.	SPACE HEATING LOAD MILLION BTU	SOLAR FRAC LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENRGY SAVINGS MILLION BTU	FCSSIL SAVING MILLION BTU	BLDG THERM DEG. F	AMB THERM DEG. F
1	*	*	*	*	*	*	*	*	*	*	*
2	*	*	*	*	*	*	*	*	*	*	*
3	3.745	3	0.111	0.769	3.636	5.441	0.184	NOT	0.000	74	60
4	5.056	0	0.000	0.737	5.956	8.926	0.000	NOT	0.000	74	47
5	4.782	6	0.275	0.616	4.507	7.134	0.455	APPL	0.000	72	50
6	2.676	0	0.000	0.315	2.676	4.356	0.000	APPL	0.000	72	60
7	1.596	0	0.000	0.210	1.596	2.418	0.000	APPL	0.000	73	70
8	0.656	0	0.000	0.099	0.656	0.937	0.000	APPL	0.000	75	76
9	0.334	0	0.000	0.054	0.334	0.528	0.000	APPL	0.000	76	77
10	0.000	0	0.000	0.000	0.000	0.000	0.000	APPL	0.000	76	78
11	0.000	0	0.000	0.000	0.000	0.000	0.000	APPL	0.000	76	78
12	1.392	0	0.000	0.303	1.392	4.322	0.000	APPL	0.000	76	63
13	3.372	0	0.000	0.647	3.372	8.938	0.000	APPL	0.000	74	56
14	2.385	0	0.000	0.465	2.389	5.737	0.000	APPL	0.000	73	64
15	2.868	0	0.000	0.693	2.868	6.720	0.000	APPL	0.000	75	62
16	3.739	3	0.115	1.006	3.623	7.039	0.192	APPL	0.000	75	58
17	3.570	8	0.295	0.750	3.275	6.350	0.491	APPL	0.000	75	59
18	1.642	0	0.000	0.365	1.642	4.068	0.000	APPL	0.000	75	69
19	1.420	0	0.000	0.312	1.420	3.670	0.000	APPL	0.000	75	69
20	0.645	0	0.000	0.205	0.645	2.317	0.000	APPL	0.000	75	74
21	1.621	7	0.113	0.415	1.508	4.110	0.189	APPL	0.000	75	67
22	2.674	0	0.000	0.558	2.674	5.848	0.000	APPL	0.000	75	62
23	2.623	0	0.000	0.535	2.623	5.726	0.000	APPL	0.000	75	61
24	4.786	0	0.000	0.923	4.786	8.956	0.000	APPL	0.000	75	53
25	6.478	0	0.000	1.421	6.478	10.197	0.000	APPL	0.000	75	45
26	4.017	0	0.000	0.737	4.017	8.485	0.000	APPL	0.000	73	53
27	3.306	0	0.000	0.620	3.306	7.758	0.000	APPL	0.000	73	57
28	3.068	0	0.000	0.566	3.068	8.030	0.000	APPL	0.000	73	59
29	3.225	1	0.032	0.617	3.192	6.226	0.054	APPL	0.000	74	64
30	*	*	*	*	*	*	*	APPL	0.000	*	*
31	1.976	0	0.000	0.433	1.976	4.443	0.000	APPL	0.000	76	66
SUM	92.544	-	1.042	15.908	81.502	164.608	1.737	N.A.	1.737	-	-
AVG	2.663	1	0.034	0.513	2.629	5.310	0.056	N.A.	0.056	74	63
NPS	Q402	N400	Q400	Q403	Q401	Q410	Q417	Q415	Q417	N406	N113

* DENOTES UNAVAILABLE DATA.
 0 DENOTES NULL DATA.
 N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SPACE COOLING SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SCLAF/9999-79/05

DAY OF MON.	SPACE COOLING LOAD MILLION BTU	SOLAR FR. OF LOAD PCT	SCLAF ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT SAVINGS MILLION BTU	FOSSIL SAVINGS MILLION BTU	BLDG DRY BULB TEMP F	AMB TEMP DEG F
1	*	*	*	*	*	*	*			*	*
2	*	*	*	*	*	*	*			*	*
3	2.009	9	0.826	1.873	6.640		10.338		1.394	74	60
4	2.057	0	0.000	2.197	7.159		10.429		0.000	74	47
5	0.904	13	0.730	1.391	4.822		7.650		1.217	72	50
6	1.468	11	0.702	2.122	6.531		10.715		1.170	72	60
7	3.893	5	0.247	2.932	10.919		16.883		0.412	73	70
8	4.588	4	0.667	3.109	13.000		20.603		1.111	75	76
9	6.311	0	0.423	3.204	13.051		20.529		0.705	76	77
10	7.102	0	0.000	3.276	11.830		19.020		0.000	76	78
11	5.382	0	0.000	3.125	9.813		16.472		0.000	76	78
12	2.385	0	0.000	2.147	6.471		8.703		0.000	74	63
13	1.538	0	0.000	1.816	5.309		4.763		0.000	76	56
14	3.429	0	0.000	2.416	7.121		9.905		0.000	74	64
15	3.904	0	0.000	2.328	7.153		9.199		0.000	73	62
16	2.076	14	0.674	1.589	3.765		4.887		1.124	75	58
17	2.922	34	1.627	1.672	3.995		5.423		2.712	75	59
18	4.171	26	1.695	2.551	6.130		8.760		2.824	75	69
19	1.752	11	0.635	2.077	4.207		6.308		1.058	75	69
20	2.173	13	0.000	2.214	5.068		8.363		0.000	75	74
21	5.209	0	0.956	2.676	7.817		11.208		1.660	75	67
22	3.225	0	0.000	2.420	6.580		9.276		0.000	75	62
23	5.029	0	0.000	2.661	8.787		12.569		0.000	75	61
24	2.257	0	0.000	1.577	4.613		5.639		0.000	75	53
25	0.000	0	0.000	0.000	0.000		0.000		0.000	75	45
26	1.046	0	0.000	1.021	3.338		3.874		0.000	73	53
27	1.273	0	0.000	1.438	4.440		5.070		0.000	73	57
28	1.575	0	0.000	1.851	5.434		6.093		0.000	73	59
29	3.182	2	0.124	2.020	6.475		9.414		0.207	74	64
30	*	*	*	*	*		*		*	*	*
31	5.357	0	0.000	2.925	9.848		14.124		0.000	76	66
SUM	96.562	-	10.358	67.123	210.710	N.A.	305.810	N.A.	17.264	-	-
AVG	3.115	5	0.334	2.165	6.797	N.A.	9.865	N.A.	0.557	74	63
NRS	Q502	N500	Q500	Q503	Q501		Q508	Q512	Q514	N406	N113

* DENOTES UNAVAILABLE DATA.

Q DENOTES NULL DATA.

N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SOLAR/5999-79/05

DAY OF MONTH	TOTAL INSOLATION RTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	*	*	*	*	N C T	N C T	N O T
2	*	*	*	*	N C T	N C T	N O T
3	2479	449	60	63	N C T	N C T	N O T
4	201	187	47	46	N C T	N C T	N O T
5	2226	335	50	58	N C T	N C T	N O T
6	2063	501	60	70	N C T	N C T	N O T
7	2073	560	70	79	N C T	N C T	N O T
8	1999	503	76	84	N C T	N C T	N O T
9	1875	642	77	86	N C T	N C T	N O T
10	1601	769	78	85	N C T	N C T	N O T
11	1377	753	78	72	N C T	N C T	N O T
12	1118	708	63	59	N C T	N C T	N O T
13	1007	575	56	73	N C T	N C T	N O T
14	1781	598	64	60	N C T	N C T	N O T
15	1690	682	62	68	N C T	N C T	N O T
16	2215	308	58	69	N C T	N C T	N O T
17	2205	323	59	78	N C T	N C T	N O T
18	2524	413	69	80	N C T	N C T	N O T
19	2023	392	69	82	N C T	N C T	N O T
20	1405	885	74	74	N C T	N C T	N O T
21	1969	682	67	69	N C T	N C T	N O T
22	1645	719	62	62	N C T	N C T	N O T
23	329	315	61	54	N C T	N C T	N O T
24	143	141	53	47	N C T	N C T	N O T
25	211	204	45	57	N C T	N C T	N O T
26	1112	860	53	59	N C T	N C T	N O T
27	1085	567	57	67	N C T	N C T	N O T
28	1509	597	59	72	N C T	N C T	N O T
29	2082	483	64	66	N C T	N C T	N O T
30	*	*	*	*	N C T	N C T	N O T
31	306	289	66	66	N C T	N C T	N O T
SUM	46878	15903	-	-	-	-	-
AVG	1512	516	63	68	N.A.	N.A.	N.A.
NBS ID	0001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
 * DENOTES NULL DATA.
 N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
THERMODYNAMIC CONVERSION EQUIPMENT

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979
SOLAR/90999-79/05

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	*	*	*	*	*
2	*	*	*	*	*
3	3.009	7.476	1.198	11.713	0.403
4	2.057	7.159	1.560	10.372	0.287
5	0.904	5.553	1.059	6.380	0.163
6	1.468	7.233	1.616	9.888	0.203
7	3.893	11.167	1.880	16.892	0.349
8	4.588	13.667	2.033	20.272	0.336
9	6.311	13.474	2.048	21.880	0.468
10	7.102	11.830	2.080	20.881	0.600
11	5.382	9.813	2.031	17.167	0.549
12	2.385	5.471	1.669	10.143	0.369
13	1.538	5.309	1.566	7.698	0.290
14	3.420	7.121	1.635	11.754	0.482
15	3.904	7.153	1.652	12.059	0.559
16	2.076	4.440	1.214	7.079	0.482
17	2.922	5.623	1.078	8.777	0.520
18	4.171	7.825	1.666	11.825	0.533
19	1.752	4.842	1.611	7.077	0.362
20	2.173	5.068	1.682	8.385	0.429
21	5.209	8.813	1.769	14.609	0.591
22	3.225	6.580	1.632	11.201	0.490
23	5.029	8.787	1.808	14.414	0.572
24	2.257	4.613	1.148	8.025	0.489
25	0.000	0.000	0.000	0.000	0.000
26	1.246	3.338	0.848	4.882	0.313
27	1.273	4.440	1.198	6.209	0.287
28	1.575	5.434	1.558	7.915	0.290
29	3.182	6.599	1.383	10.385	0.482
30	*	*	*	*	*
31	5.357	9.848	2.036	16.542	0.544
SUM	96.562	221.068	47.230	348.111	0.437
AVG	3.115	7.131	1.524	11.229	0.014

* DENOTES UNAVAILABLE DATA.

0 DENOTES NULL DATA.

N.A. DENOTES NOT APPLICABLE DATA.

NOTE:

$$\text{Coefficient of Performance} = \frac{\text{Equipment Load}}{\text{Thermal Energy Input}}$$

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
EXTRA LOAD SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: MAY, 1979

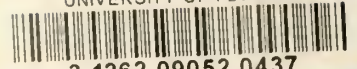
DAY OF MONTH	LOAD MILLION BTU	SOLAR FRACTION OF LOAD PERCENT	SOLAR ENERGY USED MILLION BTU	CHER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU
1	*	*	*	*	*	*	*	*	*
2	10.896	0	1.047	2.642	9.849	NOT	15.778	NOT	1.745
3	14.396	0	0.000	2.934	14.396	NOT	19.354	NOT	0.000
4	9.950	0	1.178	2.007	8.772	APPL	14.784	APPL	1.964
5	8.212	0	0.000	2.437	8.212	APPL	15.071	APPL	0.000
6	4.606	0	0.000	3.143	4.606	APPL	19.301	APPL	0.000
7	4.291	0	0.000	3.208	4.291	APPL	21.540	APPL	0.000
8	2.704	0	0.000	3.258	2.704	APPL	21.057	APPL	0.000
9	0.000	0	0.000	3.125	0.000	APPL	19.020	APPL	0.000
10	0.000	0	0.000	3.125	0.000	APPL	16.472	APPL	0.000
11	5.442	0	0.000	2.450	5.443	APPL	13.027	APPL	0.000
12	9.785	0	0.000	2.463	9.785	APPL	13.700	APPL	0.000
13	6.962	0	0.000	2.881	6.963	APPL	15.642	APPL	0.000
14	11.364	0	0.000	3.022	11.364	APPL	15.919	APPL	0.000
15	0.877	0	0.838	2.595	0.039	APPL	11.926	APPL	1.357
16	10.414	0	1.977	2.422	8.437	APPL	11.772	APPL	3.295
17	6.971	0	0.000	2.915	6.971	APPL	12.828	APPL	0.000
18	4.452	0	0.000	2.390	4.452	APPL	9.978	APPL	0.000
19	3.438	0	0.000	2.419	3.438	APPL	10.679	APPL	0.000
20	10.459	0	1.105	3.091	9.354	APPL	15.319	APPL	1.842
21	0.463	0	0.000	2.978	9.463	APPL	15.124	APPL	0.000
22	12.941	0	0.000	3.196	12.941	APPL	18.294	APPL	0.000
23	10.003	0	0.000	2.501	10.003	APPL	14.505	APPL	0.000
24	3.770	0	0.000	1.421	3.770	APPL	10.197	APPL	0.000
25	7.281	0	0.000	1.757	7.281	APPL	12.359	APPL	0.000
26	8.805	0	0.000	2.057	8.805	APPL	12.828	APPL	0.000
27	9.327	0	0.000	2.417	9.327	APPL	14.122	APPL	0.000
28	11.209	0	0.146	2.637	11.063	APPL	15.640	APPL	0.243
29	13.549	0	0.000	3.358	13.649	APPL	18.566	APPL	0.000
30	244.865	-	6.965	83.031	237.900	APPL	470.417	APPL	11.609
31	7.899	0	0.225	2.678	7.674	APPL	15.175	APPL	0.374
SUM									
AVG									

* DENOTES UNAVAILABLE DATA.
0 DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.





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